LArIAT High Voltage Hardware

March 2015

Contents

1 Introduction

LArIAT is an experiment designed to characterize particle interactions in a LArTPC. The LArTPC uses a high voltage on a cathode to drift electrons from particle ionization to anode wires to reconstruct the events.

This document describes the hardware used in the cathode high voltage system. It consists of

- A power supply
- Three high votlage cables

- Two filter pots
- A high voltage feedthrough

And is shown schematically in Figure 1.

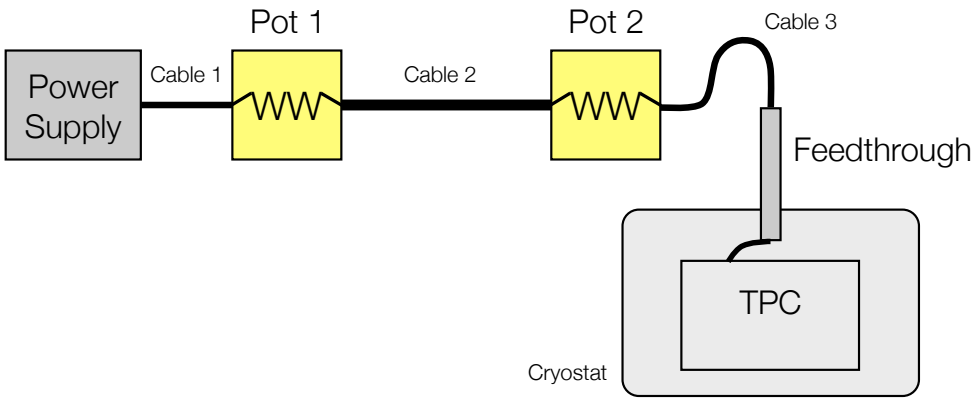


Figure 1: The LArIAT high voltage schematic.

2 Power Supply

The cathode voltage is generated by a Glassman LX125N16 power supply. This is the same supply that was successfully used in Argoneut and will be controlled by an AD interface box (detailed elsewhere). While the supply is capable of -125 kV and 16 mA, LArIAT will operate at -25 kV and draw 4 μA. In the unlikely event of a short before the end of the TPC, the filter pots described in Section 4 will limit the current.

3 Cables

Three cables are used in the cathode high voltage setup. The first is a $\frac{1}{2}$" diameter cable (Glassman item number DS 2121) that connects the power supply to the first filter pot. This cable was supplied by Glassman for the power supply. The second cable is a Dielectric Sciences cable (type 2134). Here, there is well over 100 feet of cable that connects the first filter pot in

the control room to another pot near the cryostat. The same type of cable was used in Tevatron applications, and has been used in higher voltage tests at Lab 6, DAB, and LArTF. A technical drawing is shown in Figure 2. The last cable connects the second filter pot to the high voltage feedthrough. It is the same type of $\frac{1}{2}$" cable as the power supply cable.

4 Filter Pots

There are two filter pots in the high voltage system. Their purpose is three-fold:

- Limit the current draw of the power supply.
- (in combination with the cables) Be a low-pass filter on the power supply reducing the ripple seen on the cathode.
- Partition the energy stored in the system.

The last item is the motivation for more than one pot. Should there be a discharge in the cryostat, only the energy stored down stream of the second pot would enter the cryostat quickly. On the upstream end, one worries about the power supply being exposed to a large surge of energy. The first filter pot limits this exposure.

Each filter pot consists of a pot, a flange, resistors, connectors (for the resistors), and Diala oil. The pots were made for Tevatron voltage blocks (two high voltage out lines from one in). They were made by the Lincoln corporation and have Al walls and welded tops each with an opening that allows for a flange with screws and an O-ring seal. They are 20" in diameter, 18.5" tall, and $\sim \frac{3}{16}$" thick. The flanges have receptacles that accept our high voltage cables (see Figure 3a). The receptacles are made of G10 with Al where the where the cable conductive center meets. Within each pot, the receptacles are connected to four 10 MΩ resistors (made by TRW) (see Figure 4) connected in series via the connectors (see Figures 3b). The connectors are made from machined brass and special effort has been made to round all surfaces to reduce electric fields.

The entire assembly within each pot is submerged in about 16 gallons of Diala oil (see Appendix A) to suppress any corona or discharges.

5 High Voltage Feedthrough

The last item in the high voltage chain is the high voltage feedthrough. This is a custom device made for LArIAT, but is based on the ICARUS design. It consists of a stainless steel inner conductor surrounded by a tube of ultra high molecular weight polyethylene encased in a stainless steel outer ground tube. A technical drawing of the feedthrough is shown in Figure 5, and a photo is shown in Figure 6. The feedthrough successfully held 60 kV in LAr for 95 minutes with no signs of failure.

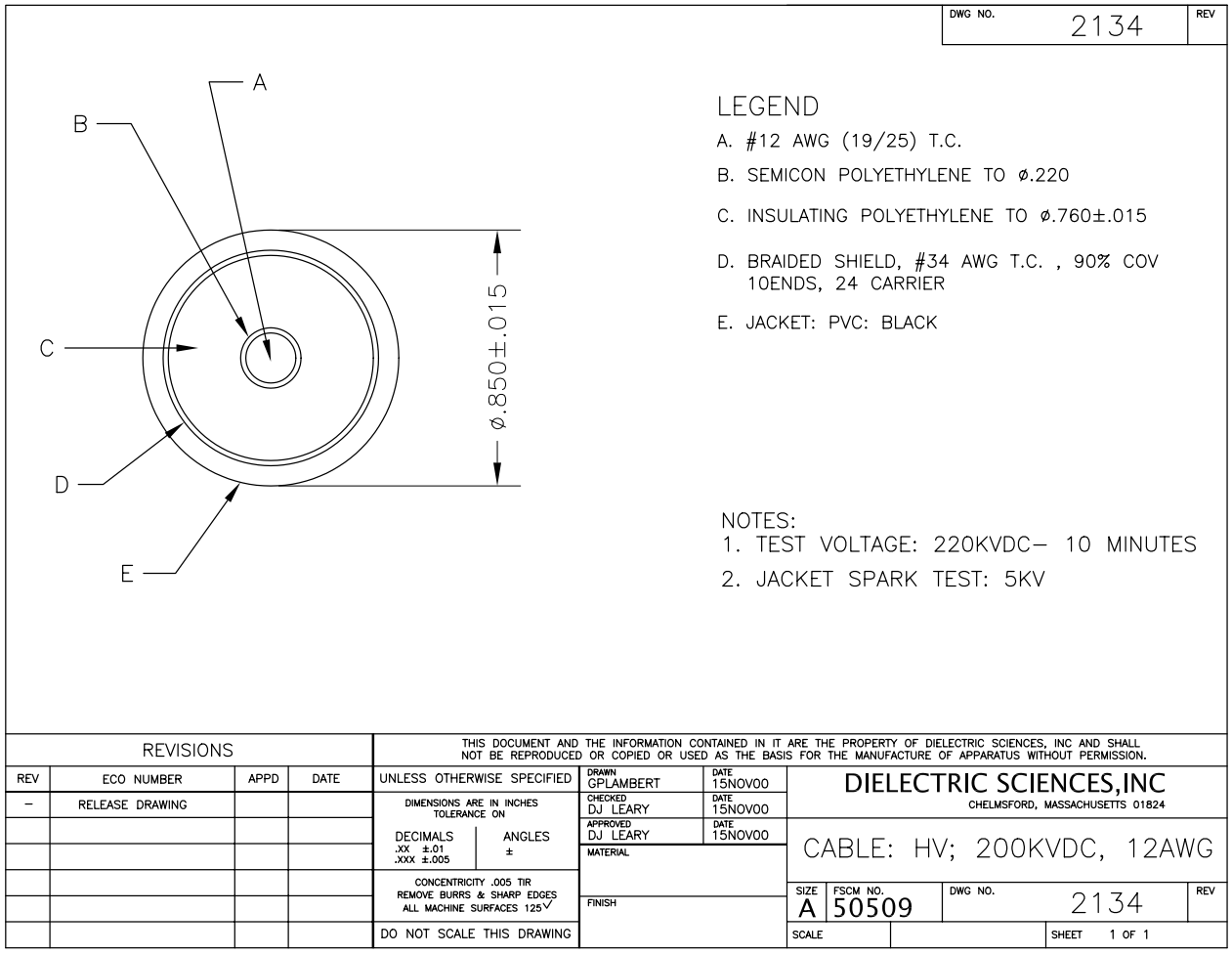
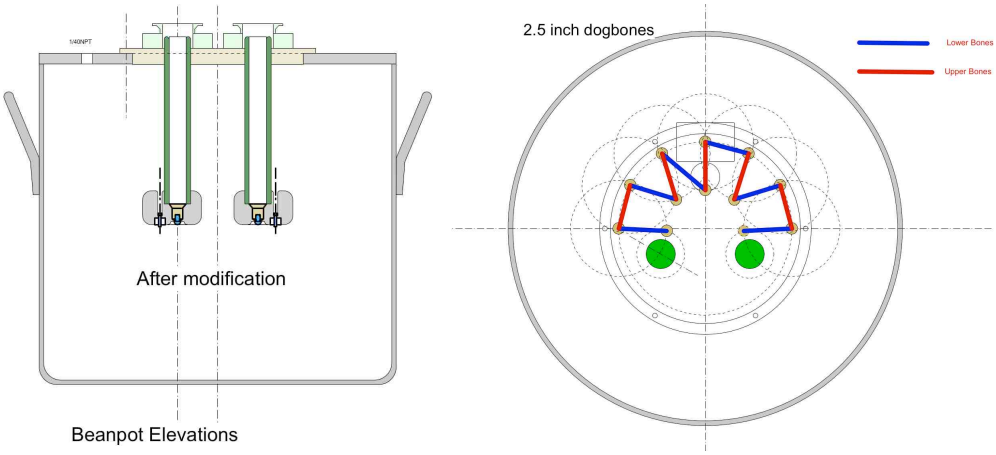


Figure 2: Drafting drawing of cross section of the Dielectric Sciences cable (2134) we use between the two filter pots.



(a) (b)

Figure 3: Schematic drawings of the filter pot. Figure 3a highlights the cable receptacles, while Figure 3b shows the arrangement of the connectors. Eight resistors are shown in this drawing, however, in each pot for LArIAT, there are only four resistors.

Figure 4: This is one of the resistors to be used in the filter pot.

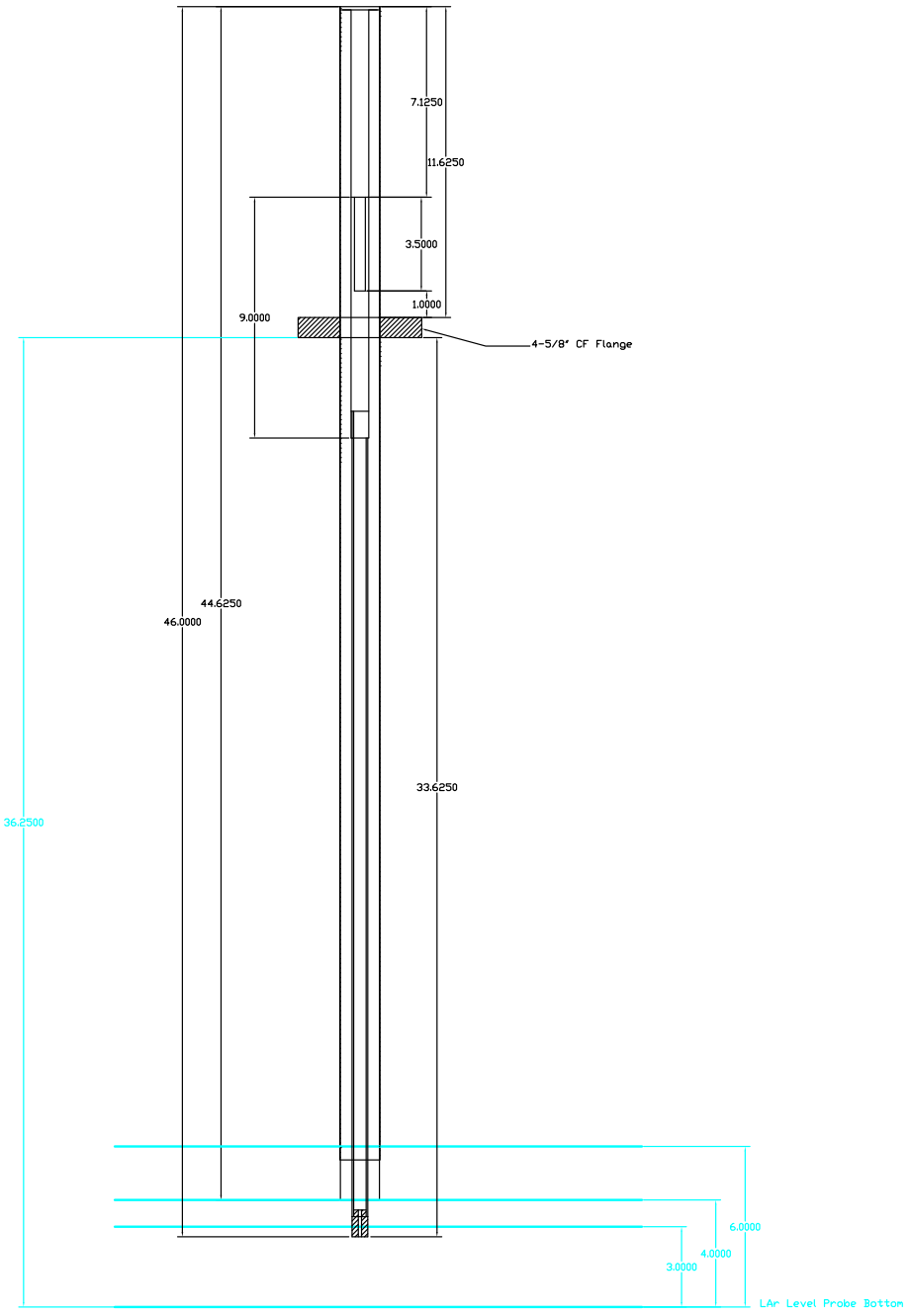


Figure 5: The drawing of the LArIAT high voltage feedthrough. Various liquid argon level elevations are shown in cyan.

Figure 6: The photo of the LArIAT high voltage feedthrough during testing.

A Diala Oil Technical Bulletin

Technical Data Sheet

Previous Name: **Shell Diala AX**

Shell **Diala *S2 ZX-A***

Inhibited electrical insulating oil

- ***RELIABLE PERFORMANCE***
- ***MEETS ASTM D3487 TYPE II***

Shell Diala S2 ZX-A is an inhibited electrical insulating oil manufactured from highly refined mineral oils. It offers good dielectric properties, good oxidation stability and provides efficient heat transfer even at low temperatures.

Shell Diala S2 ZX-A meets both the established and the new industry copper corrosion tests.

Applications

- ***Transformers***
  Electrical insulating oil for grid and industrial transformers.
- ***Electrical equipment***
  Components such as rectifiers, circuit breakers and switchgears.

Advice on applications not covered in this leaflet may be obtained from your Shell Representative.

Performance Features and Advantages

- ***Extended oil life***
  Shell Diala S2 ZX-A is an inhibited oil giving outstanding oxidation performance and an extended oil life.
- ***System efficiency***
  The good low temperature properties of the oil ensures proper heat transfer inside the transformer, even from low starting temperatures.
- ***Transformer protection***
  Shell Diala S2 ZX-A is non-corrosive towards copper, with no need for additional passivation. Shell Diala S2 ZX-A meets all relevant tests on copper corrosion ASTM D1275, and also the latest more severe tests: IEC 62535 and ASTM D1275B.

Specification and Approvals

Shell Diala S2 ZX-A meets the requirements of ANSI/ASTM D 3487 Type II

Storage precautions

The critical electrical properties of Shell Diala S2 ZX-A are easily compromised by trace contamination with foreign material. Typically encountered contaminants include moisture, particles, fibres and surfactants. Therefore, it is imperative that electrical insulating oils be kept clean and dry.
It is strongly recommended that storage containers be dedicated for electrical service and include airtight seals. It is further recommended that electrical insulating oils be stored indoors in climate-controlled environments.

Health and Safety

Guidance on Health and Safety is available on the appropriate Material Safety Data Sheet which can be obtained from your Shell representative.

Shell Diala S2 ZX-A is free from polychlorinated biphenyls (PCB).

Protect the environment

Take used oil to an authorized collection point. Do not discharge into drains, soil or water.

Typical Characteristics

Property	Units	Method	ASTM D 3487 Type II Requirement	Shell Diala S2 ZX-A
Kinematic viscosity at 0 °C	mm^2/s	ASTM D 445	max. 76	60
Kinematic viscosity at 40 °C	mm^2/s	ASTM D 445	max. 12	9
Kinematic viscosity at 100 °C	mm^2/s	ASTM D 445	max. 3	2.2
Flashpoint COC	°C	ASTM D 92	min. 145	150
Pourpoint	°C	ASTM D 97	max. -40	-57
Aniline point	°C	ASTM D 611	63-84	69
Appearance		ASTM D 1524	Clear & Bright	Clear & Bright
Density at 15 °C	kg/m^3	ASTM D 1298	max. 910	890
Interfacial tension @ 25 °C	mN/m	ASTM D 971	min. 40	42
Corrosive Sulphur		ASTM D 1275	Not corrosive	Not corrosive
Corrosive Sulphur		ASTM D 1275 B	Not corrosive	Not corrosive
Corrosive Sulphur		IEC 62535	Not corrosive	Not corrosive
Water content	mg/kg	ASTM D 1533	max. 35	<30
Oxidation Inhibitor content	%m	ASTM D 1473	max. 0.3	complies
Dielectric Breakdown Voltage		ASTM D 1816		
Oil as received	kV	ASTM D 1816 (VDE)	min. 35	40
After treatment	kV	ASTM D 1816 (VDE)	min. 56	>70
Dielectric Breakdown voltage Impulse	kV	ASTM D 3300	min. 145	>300
Dielectric Dissipation Factor (DDF) at 100 °C		ASTM D 924	max. 0.3	0.1
PCB content	mg/kg	ASTM D 4059	Not detectable	Not detectable
Oxidation Stability @ 72 hrs		ASTM D 2440		
Sludge	%m		max. 0.1	<0.01
Total acid number	mg KOH/g		max. 0.3	<0.01
Oxidation Stability @ 164 hrs		ASTM D 2440		
Sludge	%m		max. 0.2	0.01
Total acid number	mg KOH/g		max. 0.4	0.1
Oxidation Stability (RPVOT)	min	ASTM D 2112	min. 195	240
Gassing Tendency	mm^3/min	ASTM D 2300	max. 30	complies

These characteristics are typical of current production.
Whilst future production will conform to Shell's specification, variations in these characteristics may occur.

B Diala Oil MSDS

Material Safety Data Sheet

1. MATERIAL AND COMPANY IDENTIFICATION

Material Name : **Shell Diala S2 ZX-A**
Uses : Insulating oil.

Manufacturer/Supplier : **SOPUS Products**
PO BOX 4427
Houston, TX 77210-4427
USA
MSDS Request : 877-276-7285

Emergency Telephone Number
Spill Information : 877-242-7400
Health Information : 877-504-9351

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Identity	CAS No.	Concentration
Distillates (petroleum), hydrotreated light naphthenic	64742-53-6	60.00 - 100.00 %

Highly refined mineral oils and additives.
The highly refined mineral oil contains <3% (w/w) DMSO-extract, according to IP346.

3. HAZARDS IDENTIFICATION

Emergency Overview

Appearance and Odour : Clear. Liquid at room temperature. Slight hydrocarbon.

Health Hazards : Harmful: may cause lung damage if swallowed.
Safety Hazards : Not classified as flammable but will burn.
Environmental Hazards : Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Health Hazards
Inhalation : Under normal conditions of use, this is not expected to be a primary route of exposure.
Skin Contact : Prolonged or repeated skin contact without proper cleaning can clog the pores of the skin resulting in disorders such as oil acne/folliculitis.
Eye Contact : May cause slight irritation to eyes.
Ingestion : Harmful: may cause lung damage if swallowed.
Signs and Symptoms : If material enters lungs, signs and symptoms may include coughing, choking, wheezing, difficulty in breathing, chest congestion, shortness of breath, and/or fever. The onset of respiratory symptoms may be delayed for several hours after exposure. Oil acne/folliculitis signs and symptoms may include formation of black pustules and spots on the skin of exposed areas. Ingestion may result in nausea, vomiting and/or

diarrhoea.

Aggravated Medical Conditions	:	Pre-existing medical conditions of the following organ(s) or organ system(s) may be aggravated by exposure to this material: Skin.
Additional Information	:	Under normal conditions of use or in a foreseeable emergency, this product meets the definition of a hazardous chemical when evaluated according to the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

4. FIRST AID MEASURES

Inhalation	:	No treatment necessary under normal conditions of use. If symptoms persist, obtain medical advice.
Skin Contact	:	Remove contaminated clothing. Flush exposed area with water and follow by washing with soap if available. If persistent irritation occurs, obtain medical attention.
Eye Contact	:	Flush eye with copious quantities of water. If persistent irritation occurs, obtain medical attention.
Ingestion	:	If swallowed, do not induce vomiting: transport to nearest medical facility for additional treatment. If vomiting occurs spontaneously, keep head below hips to prevent aspiration. If any of the following delayed signs and symptoms appear within the next 6 hours, transport to the nearest medical facility: fever greater than 101° F (38.3°C), shortness of breath, chest congestion or continued coughing or wheezing.
Advice to Physician	:	Treat symptomatically. Potential for chemical pneumonitis. Consider: gastric lavage with protected airway, administration of activated charcoal. Call a doctor or poison control center for guidance.

5. FIRE FIGHTING MEASURES

Clear fire area of all non-emergency personnel.

Flash point	:	Typical 150 °C / 302 °F (COC)
Upper / lower Flammability or Explosion limits	:	Typical 1 - 10 %(V)(based on mineral oil)
Auto ignition temperature	:	> 320 °C / 608 °F
Specific Hazards	:	Hazardous combustion products may include: A complex mixture of airborne solid and liquid particulates and gases (smoke). Carbon monoxide. Unidentified organic and inorganic compounds.
Suitable Extinguishing Media	:	Foam, water spray or fog. Dry chemical powder, carbon dioxide, sand or earth may be used for small fires only.
Unsuitable Extinguishing Media	:	Do not use water in a jet.
Protective Equipment for Firefighters	:	Proper protective equipment including breathing apparatus must be worn when approaching a fire in a confined space.

6. ACCIDENTAL RELEASE MEASURES

Avoid contact with spilled or released material. For guidance on selection of personal protective equipment see Chapter 8 of this Material Safety Data Sheet. See Chapter 13 for information on disposal. Observe the relevant local and international regulations.

Protective measures : Avoid contact with skin and eyes. Use appropriate containment to avoid environmental contamination. Prevent from spreading or entering drains, ditches or rivers by using sand, earth, or other appropriate barriers.

Clean Up Methods : Slippery when spilt. Avoid accidents, clean up immediately. Prevent from spreading by making a barrier with sand, earth or other containment material. Reclaim liquid directly or in an absorbent. Soak up residue with an absorbent such as clay, sand or other suitable material and dispose of properly.

Additional Advice : Local authorities should be advised if significant spillages cannot be contained.

7. HANDLING AND STORAGE

General Precautions : Use local exhaust ventilation if there is risk of inhalation of vapours, mists or aerosols. Properly dispose of any contaminated rags or cleaning materials in order to prevent fires. Use the information in this data sheet as input to a risk assessment of local circumstances to help determine appropriate controls for safe handling, storage and disposal of this material.

Handling : Avoid prolonged or repeated contact with skin. Avoid inhaling vapour and/or mists. When handling product in drums, safety footwear should be worn and proper handling equipment should be used.

Storage : Keep container tightly closed and in a cool, well-ventilated place. Use properly labelled and closeable containers. Storage Temperature: 0 - 50 °C / 32 - 122 °F

Recommended Materials : For containers or container linings, use mild steel or high density polyethylene.

Unsuitable Materials : PVC.

Additional Information : Polyethylene containers should not be exposed to high temperatures because of possible risk of distortion.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational Exposure Limits

Material	Source	Type	ppm	mg/m3	Notation
Distillates (petroleum), hydrotreated light naphthenic	OSHA Z1	PEL	500 ppm	2,000 mg/m3	

Distillates (petroleum), hydrotreated light naphthenic	OSHA Z1A	TWA	400 ppm	1,600 mg/m3	
Distillates (petroleum), hydrotreated light naphthenic	ACGIH	TWA(Inhalable fraction.)		5 mg/m3	

Oil mist, mineral	ACGIH	TWA(Inhalable fraction.)		5 mg/m3	
Oil mist, mineral	OSHA Z1	PEL(Mist.)		5 mg/m3	
Oil mist, mineral	OSHA Z1A	TWA(Mist.)		5 mg/m3	
Oil mist, mineral	OSHA Z1	(Mist.)			Listed.

Additional Information : Shell has adopted as Interim Standards the OSHA Z1A values that were established in 1989 and later rescinded.

Exposure Controls : The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Select controls based on a risk assessment of local circumstances. Appropriate measures include: Adequate ventilation to control airborne concentrations. Where material is heated, sprayed or mist formed, there is greater potential for airborne concentrations to be generated.

Personal Protective Equipment : Personal protective equipment (PPE) should meet recommended national standards. Check with PPE suppliers.

Respiratory Protection : No respiratory protection is ordinarily required under normal conditions of use. In accordance with good industrial hygiene practices, precautions should be taken to avoid breathing of material. If engineering controls do not maintain airborne concentrations to a level which is adequate to protect worker health, select respiratory protection equipment suitable for the specific conditions of use and meeting relevant legislation. Check with respiratory protective equipment suppliers. Where air-filtering respirators are suitable, select an appropriate combination of mask and filter. Select a filter suitable for combined particulate/organic gases and vapours [boiling point >65°C(149 °F)].

Hand Protection : Where hand contact with the product may occur the use of gloves approved to relevant standards (e.g. Europe: EN374, US: F739) made from the following materials may provide suitable chemical protection: PVC, neoprene or nitrile rubber

		gloves. Suitability and durability of a glove is dependent on usage, e.g. frequency and duration of contact, chemical resistance of glove material, glove thickness, dexterity. Always seek advice from glove suppliers. Contaminated gloves should be replaced. Personal hygiene is a key element of effective hand care. Gloves must only be worn on clean hands. After using gloves, hands should be washed and dried thoroughly. Application of a non-perfumed moisturizer is recommended.
Eye Protection	:	Wear safety glasses or full face shield if splashes are likely to occur.
Protective Clothing	:	Skin protection is not required under normal conditions of use. It is good practice to wear chemical resistant gloves.
Monitoring Methods	:	Monitoring of the concentration of substances in the breathing zone of workers or in the general workplace may be required to confirm compliance with an OEL and adequacy of exposure controls. For some substances biological monitoring may also be appropriate.
Environmental Exposure Controls	:	Minimise release to the environment. An environmental assessment must be made to ensure compliance with local environmental legislation.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	:	Clear. Liquid at room temperature.
Odour	:	Slight hydrocarbon.
pH	:	Not applicable.
Initial Boiling Point and Boiling Range	:	> 280 °C / 536 °F estimated value(s)
Pour point	:	Typical -57 °C / -71 °F
Flash point	:	Typical 150 °C / 302 °F (COC)
Upper / lower Flammability or Explosion limits	:	Typical 1 - 10 %(V) (based on mineral oil)
Auto-ignition temperature	:	> 320 °C / 608 °F
Vapour pressure	:	< 0.5 Pa at 20 °C / 68 °F (estimated value(s))
Specific gravity	:	Typical 0.890 at 15 °C / 59 °F
Density	:	Typical 890 kg/m3 at 15 °C / 59 °F
Water solubility	:	Negligible.
n-octanol/water partition coefficient (log Pow)	:	> 6 (based on information on similar products)
Kinematic viscosity	:	Typical 9 mm2/s at 40 °C / 104 °F
Vapour density (air=1)	:	> 1 (estimated value(s))
Evaporation rate (nBuAc=1)	:	Data not available

10. STABILITY AND REACTIVITY

Stability	:	Stable.
Conditions to Avoid	:	Extremes of temperature and direct sunlight.
Materials to Avoid	:	Strong oxidising agents.
Hazardous Decomposition Products	:	Hazardous decomposition products are not expected to form during normal storage.

11. TOXICOLOGICAL INFORMATION

Basis for Assessment	:	Information given is based on data on the components and the toxicology of similar products.
Acute Oral Toxicity	:	Expected to be of low toxicity: LD50 > 5000 mg/kg , Rat Aspiration into the lungs may cause chemical pneumonitis which can be fatal.
Acute Dermal Toxicity	:	Expected to be of low toxicity: LD50 > 5000 mg/kg , Rabbit
Acute Inhalation Toxicity	:	Not considered to be an inhalation hazard under normal conditions of use.
Skin Irritation	:	Expected to be slightly irritating. Prolonged or repeated skin contact without proper cleaning can clog the pores of the skin resulting in disorders such as oil acne/folliculitis.
Eye Irritation	:	Expected to be slightly irritating.
Respiratory Irritation	:	Inhalation of vapours or mists may cause irritation.
Sensitisation	:	Not expected to be a skin sensitiser.
Repeated Dose Toxicity	:	Not expected to be a hazard.
Mutagenicity	:	Not considered a mutagenic hazard.
Carcinogenicity	:	Product contains mineral oils of types shown to be non-carcinogenic in animal skin-painting studies. Highly refined mineral oils are not classified as carcinogenic by the International Agency for Research on Cancer (IARC). Other components are not known to be associated with carcinogenic effects.
Reproductive and Developmental Toxicity	:	Not expected to be a hazard.
Additional Information	:	Used oils may contain harmful impurities that have accumulated during use. The concentration of such impurities will depend on use and they may present risks to health and the environment on disposal. ALL used oil should be handled with caution and skin contact avoided as far as possible.

12. ECOLOGICAL INFORMATION

Ecotoxicological data have not been determined specifically for this product. Information given is based on a knowledge of the components and the ecotoxicology of similar products.

Acute Toxicity	:	Poorly soluble mixture. May cause physical fouling of aquatic organisms. Expected to be harmful: LL/EL/IL50 10-100 mg/l (to aquatic organisms) (LL/EL50 expressed as the nominal amount of product required to prepare aqueous test extract).
Mobility	:	Liquid under most environmental conditions. Floats on water. If it enters soil, it will adsorb to soil particles and will not be mobile.
Persistence/degradability	:	Expected to be not readily biodegradable. Major constituents are expected to be inherently biodegradable, but the product contains components that may persist in the environment.
Bioaccumulation	:	Contains components with the potential to bioaccumulate.
Other Adverse Effects	:	Product is a mixture of non-volatile components, which are not

expected to be released to air in any significant quantities. Not expected to have ozone depletion potential, photochemical ozone creation potential or global warming potential.

13. DISPOSAL CONSIDERATIONS

Material Disposal	:	Recover or recycle if possible. It is the responsibility of the waste generator to determine the toxicity and physical properties of the material generated to determine the proper waste classification and disposal methods in compliance with applicable regulations. Do not dispose into the environment, in drains or in water courses.
Container Disposal	:	Dispose in accordance with prevailing regulations, preferably to a recognised collector or contractor. The competence of the collector or contractor should be established beforehand.
Local Legislation	:	Disposal should be in accordance with applicable regional, national, and local laws and regulations.

14. TRANSPORT INFORMATION

US Department of Transportation Classification (49CFR)
This material is not subject to DOT regulations under 49 CFR Parts 171-180.

IMDG
This material is not classified as dangerous under IMDG regulations.

IATA (Country variations may apply)
This material is either not classified as dangerous under IATA regulations or needs to follow country specific requirements.

15. REGULATORY INFORMATION

The regulatory information is not intended to be comprehensive. Other regulations may apply to this material.

Federal Regulatory Status

Notification Status

EINECS	All components listed or polymer exempt.
TSCA	All components listed.
DSL	All components listed.

Shell classifies this material as an "oil" under the CERCLA Petroleum Exclusion, therefore releases to the environment are not reportable under CERCLA.

State Regulatory Status

California Safe Drinking Water and Toxic Enforcement Act (Proposition 65)

This material does not contain any chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

New Jersey Right-To-Know Chemical List

Distillates (petroleum), hydrotreated light naphthenic (64742-53-6)	Listed.

Pennsylvania Right-To-Know Chemical List

Distillates (petroleum), hydrotreated light naphthenic (64742-53-6)	Listed.

16. OTHER INFORMATION

NFPA Rating (Health, Fire, Reactivity)	:	0, 1, 0
MSDS Version Number	:	1.2
MSDS Effective Date	:	09/07/2011
MSDS Revisions	:	A vertical bar (|) in the left margin indicates an amendment from the previous version.
MSDS Regulation	:	The content and format of this MSDS is in accordance with the OSHA Hazard Communication Standard, 29 CFR 1910.1200.
MSDS Distribution	:	The information in this document should be made available to all who may handle the product.
Disclaimer	:	The information contained herein is based on our current knowledge of the underlying data and is intended to describe the product for the purpose of health, safety and environmental requirements only. No warranty or guarantee is expressed or implied regarding the accuracy of these data or the results to be obtained from the use of the product.